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THERMOACOUSTIC REFRIGERATION SYSTEM

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ABSTRACT

Cooling is generally obtained by vapour compression system using a specific refrigerant. But it has been recently found that the refrigerants are known to cause adverse environmental effects. In order to save our environment, it is a must that we develop new alternative refrigeration technologies like thermo acoustic refrigeration system, avoiding environmentally hazardous refrigerants.

In this study, a thermo acoustic refrigerator (TAR) uses sound waves to provide cooling. Here the device is designed, consisting of a acoustic wave generation device regulated to the channel of a hollow tube, with a stack at a predetermined position in the channel of the tube. From the acoustic wave generation device, an acoustic wave emitted, achieving a temperature gradient across the stack.

KEYWORDS: Thermo Acoustic Refrigeration, Stack, Acoustic Resonator Tube, Thermocouple & Temperature Indicator

Original Article

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INTRODUCTION

During the past few years, both engineers and physicists have been working on heat engines and compression-driven refrigerators without oscillating pistons, oil-seals or lubricants. This device used the principle of the sound wave vibrant within them to convert a temperature differential into mechanical energy or mechanical energy into a temperature differential to generate electricity or to provide refrigeration and air-conditioning. Thermo acoustic device uses the eco-friendly inert gases as the working fluid, saving the environment from global warming or stratospheric ozone depletion caused by the refrigerants CFCs and HFCs. Acoustics is the study of sound production, transmission and effects, and thermo acoustics is the study of thermal effects of the sound waves and the interconversion of the sound energy and heat. Thermo acoustic device is of two types: thermo acoustic engine (prime mover) and thermo acoustic refrigerator. The working principle used in thermo acoustic engine is the conversion of heat into sound energy. Here the heat flows from a source at higher temperature to a sink at a lower temperature, whereas in thermo acoustic refrigerator, it is the vice versa. Loudspeakers or electro-dynamic shakers convert electrical power into acoustic power. Sound waves produce heat and this technology uses the sound enregy to pump heat across a temperature gradient.

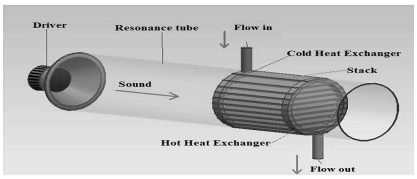


Figure 1: Sound Wave Thermo Acoustic Refrigerator

Thermo acoustic refrigeration system consists of a loudspeaker attached to an acoustic resonator (tube) filled with a gas. In the tube, a stack consisting of a number of parallel plates and two heat exchangers are installed, one for the purpose of cooling and the other for hot thermal energy. The sub-compartments are separated by plates whose spatial distance decides the region of heat flux caused by the functioning fluid. The acoustic standing wave displaces the gas in the channels of the stack while compressing and expanding, respectively, leading to heating and cooling of the gas. The gas, which is cooled due to expansion, absorbs heat from the cold part of the stack and as it subsequently heats up due to compression while moving to the hot side rejects the heat to the stack. The heat is exchanged with the surroundings, at the cold and heat sides of the stack, enabling the refrigeration process.

DESIGN OF THERMOACOUSTIC REFRIGERATOR

The standing-wave thermo acoustic refrigerators are of simple configuration. A standing-wave TAR consists of a driver, a resonator, and a stack. The two heat exchangers are not really necessary for creating a difference in the temperature across the stack. A modified electro dynamic loudspeaker, the driver, is sealed to a resonator. The resonator will respond to a standing pressure wave, assuming the driver is supplied with proper frequency input, increasing the input from the driver. Within the stack, the standing wave drives the thermo acoustic process. The word stack was conceived from the stack of parallel plates, however, the term refers to the thermo acoustic core of a standing wave TAR without bothering core's geometry. Within the resonator, the stack is placed in between a pressure antinode and a velocity antinode in the sound wave. Through the thermo acoustic process, the heat is pumped to the pressure antinode. Now the device is called a refrigerator or heat pump, depending on the attachment of heat exchangers for practical application. With or without the heat exchangers, a temperature gradient can be created along the stack. Heat hardly flows through the exchangers. When the hot end is thermally anchored to the environment and the cold end connected to a heat load, device operates as a heat pump.

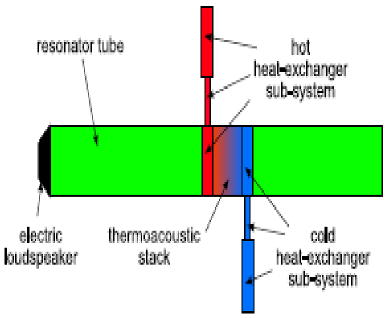


Figure 2: Schematic Diagram Thermo Acoustic Refrigeration

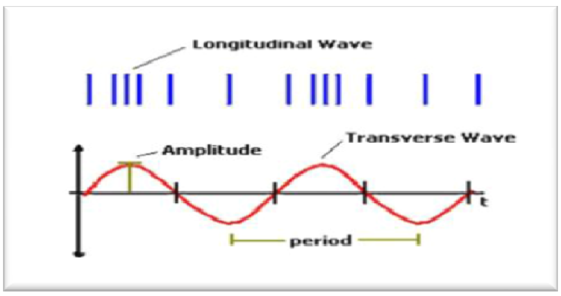


Figure 3: Behavior of Gas Molecules

The gas parcel undergoes adiabatic compression and due to acoustic wave, it travels up the channel. Due to double-fold increase in acoustic pressure amplitude, temperature of the gas increases. In the second step, on attaining maximum displacement, the parcel obtains a higher temperature than the adjacent walls, assuming the imposed temperature gradient is sufficiently small. Therefore, the parcel undergoes an isobaric process during which it rejects heat to the wall, resulting in a decrease in the size and temperature of the gas parcel. Therefore, the gas parcel goes through an isobaric process wherein it rejects heat to the walls, thereby decreasing the temperature and size of the gas parcel. In step three, the second half-cycle of the acoustic oscillation moves the gas parcel back down the temperature gradient. As the pressure becomes minimum, the gas parcel expands adiabatically, reducing the temperature of the gas. The gas reaches its maximum spin in the opposite direction, with a larger volume and lower temperature.

DESIGN SPECIFICATIONS

The table lists the materials used in the thermo acoustic refrigeration system fabrication. The resonator consists of a 60-mm diameter glass tube, and the stack of polyester film.

Table 1

S.no	Item Name	Size	Qty	Material
1	Acrylictube	L=60cm,D=6cm	1	Acrylic
2	Temperature indicator	12 Switches	1	
3	Thermocouples		6	
4	Speakerandamplifier	15 Watts	1	
5	Stack		1	Polyester film
6	Supportingframe	80 × 40 × 10	1	Mild steel

Figure 4: Experimental Setup of Thermo Acoustic Refrigerator

RESULTS

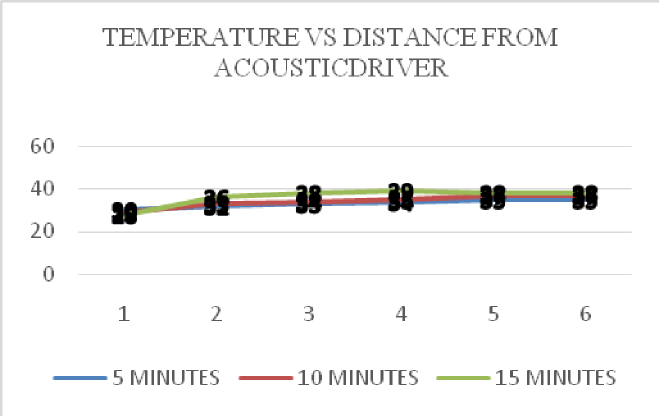
The functioning of a thermo acoustic refrigeration system was understood based on experimental analysis arriving at a temperature difference of 7 degree celsius (avg) between the two ends of the resonator tube. The table presents the experimental values, and the graph shows the temperature and distance from the acoustic driver.

Table 2

THERMOCOUPLE NO.	1	2	3	4	5	6
Distance fromacoustic resonator (cm)	2	12	23	35	48	60
Time (minutes)	Temperature in (°C)					
5	30	32	33	34	35	35
10	29	33	34	35	37	37
15	29	36	38	39	38	38

Graph

From the values recorded, a graph in drawn



Graph 1

Cost Analysis

Table 3

Item Name	Size	Qty	Cost
Acrylic tube	60 cm	1	1000
Temperatureindicator	12 Switches	1	1000
Thermocouples		6	600
Speakerandamplifier		1	2000
Stack		1	200
Supportingframe	80 × 40 × 10	1	1000
Total			**5800**

CONCLUSIONS

To serve as a good refrigeration system, thermo acoustics seems to be a propitious area. The main intention of this study was to develop a simple thermo acoustic refrigerator, that is 100 percent functional. This paper reveals the design and fabrication of a simple thermo acoustic refrigeration system with inexpensive and readily available materials. Practical considerations and performance estimate that in a given operating condition, a temperature gradient of 7 degree Celsius could be established across the stack. This device is a concept device, proving the possibility of a thermo acoustic device, with an ability to cool air only for a short period of time. It is also noted that for best performance of the system wisely choosing the operating parameters is essential.

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